APPLICATION FOR UNITED STATES LETTERS PATENT

METHOD FOR MANUFACTURING STRUCTURAL PARTS FOR AUTOMOBILE BODY CONSTRUCTION

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BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to elongate structural parts as safety elements for automobile body construction, known in the form of lateral impact supports, bumpers, and column reinforcements. Because of more stringent requirements, the use of high strength and highest strength steels has increased. The structural parts, in general, are manufactured as pressed parts from sheet metal blanks or by shaping and stamping tubes. However, they can also be produced by edge rolling/profiling of steel strip. In addition to a very high strength, such structural parts must have a minimum ductility of 5 % to 10 %.

2. Description of the Related Art

It is known in the art to employee cold-formable, high strength steels. Such steels are suitable, however, only for structural parts with a simple profiling/shaping because of their limited shaping and deforming properties.

It is also known in the prior art to use hardenable steels. These steels in the form of blanks or tubes are

first shaped to structural parts while still soft. The structural parts are then provided with the required strength in a subsequent hardening process. Since these steels in their soft state have excellent shaping and deforming properties, it is possible to produce complex profiled structural parts from them. One material with these properties is, e.g., 22 Mn 5 mod. This material has in its soft state a strength of approximately 600 N/mm^2 and a ductility of greater than 30 %. After hardening, strength values of up to 1600 N/mm^2 with 10% ductility can be achieved.

Heating to the austenitizing temperature for the purpose of hardening is frequently performed in the art by gas-heated or electrically heated continuous furnaces. In order to ensure a continuous production, such continuous furnaces are integrated into the manufacturing line for the structural parts. However, a disadvantage is the great space requirement of such continuous furnaces. Furthermore, it should be noted that energy consumption is considerable and that heat losses cannot be avoided. Also, when using continuous furnaces, it is not possible to perform a partial or regional hardening of the structural parts.

Finally, it is also known to shape the hardenable

steels to the desired structural parts with combination shaping and hardening tools. In this case, the blanks or tubes are heated before shaping to the austenitizing temperature and are then simultaneously shaped and hardened in a cooled shaping tool. This process also necessarily entails high tool and energy technological expenditures. Furthermore, this process increases considerably the length of the shaping step work cycle.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method for manufacturing elongate structural parts for automobile body construction that have at least regionally a high strength and a minimum ductility of 5 % to 10 %, the structural parts performing safety functions in the automobile body, wherein the method should require only minimal manufacturing and tool expenditure and should ensure a high efficiency with reduced energy consumption.

In accordance with the present invention, this is achieved in that each structural part is first shaped or configured by shaping blanks, steel strip, or tubes of hardenable steel in the soft state; is heated subsequently, in a substantially vertical position, at least regionally to the austenitizing temperature required for hardening by an induction element, surrounding the structural part and movable relative to the structural part from the bottom to the top so as to follow the contour of the structural part; and is finally cooled by a cooling unit following the induction element in the direction of movement.

With this method hardenable steels, for example, 22 Mn B5 mod., can be used. The blanks or tubes of hardenable

steel are shaped in the soft state to the desired configuration of the structural parts. The structural parts, however, can also be manufactured by edge rolling/profiling of steel strip. In the context of the present invention, the term blank is meant to include sheet metal blanks or pieces, tubes, and steel strips or bands. The structural parts can be designed as open or closed profile members. The profile cross-sections can vary between the structural parts and can be of different complexity. Furthermore, the profile cross-sections can change over the length of the structural parts. Also, the structural parts can be provided without problems with curvatures and bent portions. The wall thickness of the structural parts can be extremely small. In general, the wall thickness is in the range of 1 mm to 3 mm.

After configuration of the structural parts they are then hardened while being substantially vertically positioned. Heating during hardening is realized by means of an induction element that can be moved relative to the structural parts along their length, i.e., in the longitudinal direction. The induction element surrounds the structural parts and the shape of the induction element is matched to the cross-section of the structural parts. The induction element can be an induction coil with a single

winding or several windings. A plate induction element is also feasible. One advantage of a plate-shaped induction element is that it provides improved efficiency and ensures a more uniform heating of the diverse cross-sections when used on complex pressed parts with varying cross-sections.

When the induction element is appropriately designed, it can simultaneously heat at least two adjacently positioned structural parts. For this purpose, the induction element surrounds all structural parts.

For achieving a uniform strength over the entire profile cross-section, a uniform heating must be ensured. For this purpose, the induction element can be matched to each of the structural parts as needed. Furthermore, it is possible without problems to select a frequency for the induction current that is matched to the structural parts. When the cross-sections of the structural parts change over the length of the structural parts, the advancing speed of the induction element and/or the power can be adjusted in order to ensure at all times a uniform heating temperature over the length of the structural part as well as across the entire cross-section.

The cooling of the heated structural parts is carried

out with the aid of a cooling unit which follows the induction element in its direction of movement. The induction element and the cooling unit can be moved upwardly relative to the position-fixated structural parts (from the bottom to the top) or, alternatively, the structural parts can be moved downwardly (from the top to the bottom) relative to the induction element and the cooling unit arranged below it. In this manner, it is ensured that the respective cooling medium comes into contact with the structural parts only after they have been heated so that heating and cooling are definitely separated from one another by a certain amount of time. Furthermore, contact of the liquid cooling medium with the induction element is prevented, and the risk of voltage flashover is eliminated.

The induction element and the cooling unit are guided along the contour of the structural part such that the two device components are positioned at all times substantially perpendicularly to the center axis of the cross-section of the structural part. This ensures a heating and cooling action as uniform as possible even for complex, spatially curved structural parts.

Since it is inventively possible without problems to guide the induction element together with the cooling unit

only over certain predetermined regions of the structural parts and provide only these regions with the desired strength, it is possible to fulfill different strength requirements in the individual regions of the structural parts. In comparison to continuous furnaces, the inventive method provides substantial cost savings in regard to the device to be used as well as to the energy consumption. Furthermore, another advantage is the minimization of the hardening distortion of the structural part.

With the inventively envisioned partial hardening a directed adjustment of crash or failure behavior of the structural parts can be achieved. The non-hardened regions of the structural parts then form the constructively desired folding and crumple (collapsible) zones which enhance the predefined deformation of the structural parts. In this context, a directed local adjustment of the strength values with regard to the component load can be provided, e.g., in analogy to the so-called tailored blanks comprised of different steel quality. However, in contrast to the tailored blanks, any type of welding seam is eliminated when employing inductive hardening as suggested with the method of the invention. Furthermore, wide transitional strength zones can be realized, and an abrupt strength jump is thus prevented.

In order to adapt the hardening process to the requirements of different steel qualities with respect to the cooling rate, different types of cooling media can be used for cooling the structural parts.

Moreover, the hardening distortion, which cannot be prevented during hardening, can however be reduced by a suitable fixation of the structural parts during hardening. The degrees of freedom of the securing means accordingly can directly influence the distortion behavior. Also, already during shaping of the structural parts from blanks or tubes or by edge rolling of steel strip it is possible to take into account later hardening distortions by providing a respectively adjusted shape. An improved dimensional precision of the structural parts will result. In order to allow a simple adjustment to structural parts of different configurations, the securing means can be of a flexible design for accommodating various configurations.

According to a further embodiment of the invention, the induction element and the cooling unit can be position-adjusted relative to one another. The adjustability of the spacing between the induction element and the cooling unit can be used to affect the cooling rate and thus the hardness or strength of the structural parts.

According to a preferred embodiment, the cooling unit can be a divided into several cooling elements in the circumferential direction of the structural part in order to thus influence more precisely the hardening distortion.

In this context, it is possible to position-adjust the individual cooling elements relative to one another in order to influence even more precisely the hardening distortion.

According to another inventive embodiment, the induction element is operated at high frequency. For this purpose, frequencies of 400 kHz to 800 kHz are especially advantageous. In this manner, complex, thin-walled structural parts can be heated substantially uniformly over the entire cross-section. At these high frequencies, the induced eddy current in the structural parts is substantially uniformly distributed over the cross-section.

Via the cooling unit the structural parts can be subjected to different cooling media. According to one embodiment of the invention, each structural part is subjected to a liquid stream in the area of the cooling unit. The cooling liquid can be, e.g., water, oil or an oil/water mixture. By adjusting the volume stream and pressure of the cooling medium, the cooling rate can be

determined and the microstructure and thus the hardness according to the time-temperature-conversion diagram can be significantly influenced.

Another possibility of subjecting the structural parts to a cooling medium is to provide a liquid mist that is sprayed onto the structural part in the area of the cooling unit. Such a liquid mist is finely atomized. This produces a gentler cooling in comparison to the abrupt cooling action of a liquid. It is also possible to realize an incomplete cooling of the structural parts, i.e., a certain residual heat is retained in the structural part which then results in self-tempering of the structural part.

It is also possible to subject each structural part in the area of the cooling unit to a gaseous medium. The gaseous medium may be air or compressed air or an inert gas. An inert gas prevents at the same time scale formation at the structural part. In this manner a possibly required scale removal, for example, by sand blasting, can be eliminated. Also, possible decarburization of the material of the structural part can be prevented. As with the liquid mist, it is also possible to retain a certain residual heat in the structural part when employing a gaseous medium. The residual heat then results in self-tempering of the

structural part.

Moreover, it is possible to employ a gaseous cooling medium or a liquid mist in combination with a liquid for cooling of the heated structural part. Accordingly, a slow cooling action by a gas stream or a liquid mist and a subsequent quenching with a liquid can be performed. The cooling units with the different cooling media are arranged at a different spacing below the induction element. In this way, a defined course of the cooling curve within the time-temperature-conversion diagram is possible.

It is also possible to heat the structural parts with the same induction element to a tempering temperature after hardening.

The decisive advantages of the inventive method are as follows:

- an increased efficiency of heat introduction;

- reduced space requirements;

- each structural part can be partially hardened as desired according to specific requirements.

This results in a simplified integration into the entire manufacturing facility.

- No hot structural parts must be manipulated because by means of the cooling unit a quenching action is performed within the hardening device.

- The scale formation at structural parts is considerably reduced.

- Wear and tear on the device and servicing costs are significantly reduced because movable parts of the hardening device are not heated.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

Fig. 1 is a perspective view showing schematically a structural part for automobile body construction together with an induction element and a cooling unit;

Fig. 2 is a horizontal cross-section of the representation of Fig. 1 in the plane II-II viewed in the direction of arrows IIa;

Fig. 3 shows schematically a side view of a device for hardening a structural part similar to that of Fig. 1;

Fig. 4 is a perspective view showing schematically a structural part for automobile body construction according to a further embodiment together with an induction element and a cooling unit;

Fig. 5 is a horizontal cross-section of the representation of Fig. 4 in the plane V-V viewed in the direction of arrows Va;

Fig. 6 is a perspective view showing schematically two

structural parts for automobile body construction together with an induction element and a cooling unit; and

Fig. 7 is a horizontal cross-section of the representation of Fig. 6 in the plane VII-VII viewed in the direction of arrows VIIa.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The Figures 1 and 2 show a structural part 1 in the form of a lateral impact support. The structural part 1 comprises between the fastening ends 2, 2a two grooves 3 that have a trapezoidal cross-section with flanks 4 connected by a stay 5. For such a structural part 1 it is desirable to provide a certain strength at least over a portion of its length L.

For this purpose, the structural part 1, or a structural part 1' according to Fig. 3, is connected for hardening in a substantially vertical position with its lower end 2 at a thrust bearing 6 of the device 7. The upper end 2a of the structural part 1 is secured in a non-locating or floating bearing 8 of the device 7.

The thrust bearing 6 as well as the non-locating bearing numeral 8 are components of a column 9 which is positioned above the catch basin 10 for catching a liquid cooling medium. The catch basin 10 is provided with a drain 11 for removing the heated cooling medium for the purpose of cooling and filtering.

The structural part 1, 1' is surrounded according to

the representations of Figures 1 and 3 by an induction element 12 having a cross-section that is substantially matched to the structural part 1, 1'. The induction element 12 is operated at a frequency of 400 to 600 kHz, as is schematically illustrated in Fig. 1. It is cooled by a cooling medium. The inlets and outlets for the cooling medium are identified by reference numerals 13 and 14.

At the spacing below the induction element 12 a cooling unit 15 is provided which can be adjusted in regard to the spacing relative to the induction element 12. The cooling unit 15 also surrounds the structural part 1, 1'. The cooling unit 15 in the shown embodiment is cooled by a cooling medium in the form of an emulsion of water and oil. The inlets and outlets for the cooling medium are identified by reference numerals 16 and 17.

As can be seen in Fig. 1, the cooling unit 15 can be divided in the circumferential direction into different cooling elements 18. These cooling elements 18 can be position-adjusted relative to one another.

Fig. 3 shows also that the induction element 12 and the cooling unit 15 are connected to the tool carriage 19. The carriage 19 can be moved according to the double arrow 20

along the guides 21 of the column 9 in the vertical direction, according to the double arrow 22 in the transverse direction, and according to the double arrow 23 about a horizontal axis 24. In this way it is possible to guide the induction element 12 and the cooling unit 15 in a directed manner according to the contour of the structural part 1'.

In Fig. 4 a structural part 1a in the form of a reinforcement for a B-column of a passenger car is represented in a perspective view. Fig. 5 shows the cross-section of the structural part 1a at the lower end 25. The structural part 1a is highly loaded only in the connecting region at the door sill of the passenger car so that it requires an increased strength only in this area.

For this purpose, the structural part 1a is secured in a substantially vertical position at the lower end 25 and the upper end 26 by non-represented securing means of the column 9. The longitudinal area L1 of the structural part 1a is hardened by passing an induction element 12a, whose contour is matched to the cross-section of the structural part 1a and which has a cooling unit 15a arranged therebelow, in the longitudinal direction (arrow 27) from the bottom to the top along the longitudinal area L1. The

longitudinal area L1 can be heated by the induction element 12a to the austenitizing temperature required for hardening and can be cooled (quenched) by means of the cooling unit 15a.

In Figures 6 and 7 it is shown how simultaneously two structural parts 1b of a trapezoidal cross-section can be heated by an induction element 12b in the form of a plate induction element and can be cooled with a following cooling unit 15b arranged below the induction element 12b.

In other respects, the method sequence corresponds to the method disclosed in connection with Figures 1 through 3 so that reference is made to the above explanations of the method steps. A device 7 according to Fig. 3 can also be used when its design is correspondingly adapted.

While specific embodiments of the invention have been shown and described in detail to illustrate the inventive principles, it will be understood that the invention may be embodied otherwise without departing from such principles.